APPLICATION

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TITLE: **MODULATION OF HAIR GROWTH**

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MODULATION OF HAIR GROWTH

Background of the Invention

The invention relates to modulating hair growth in mammals.

A main function of mammalian hair is to provide environmental protection. However, that function has largely been lost in humans, in whom hair is kept or removed from various parts of the body essentially for cosmetic reasons. For example, it is generally preferred to have hair on the scalp but not on the face.

Various procedures have been employed to remove unwanted hair, including shaving, electrolysis, depilatory creams or lotions, waxing, plucking, and therapeutic antiandrogens. These conventional procedures generally have drawbacks associated with them. Shaving, for instance, can cause nicks and cuts, and can leave a perception of an increase in the rate of hair regrowth. Shaving also can leave an undesirable stubble. Electrolysis, on the other hand, can keep a treated area free of hair for prolonged periods of time, but can be expensive, painful, and sometimes leaves scarring. Depilatory creams, though very effective, typically are not recommended for frequent use due to their high irritancy potential. Waxing and plucking can cause pain, discomfort, and poor removal of short hair. Finally, antiandrogens -- which have been used to treat female hirsutism -- can have unwanted side effects.

It has previously been disclosed that the rate and character of hair growth can be altered by applying to the skin inhibitors of certain enzymes. These inhibitors include inhibitors of 5-alpha reductase, ornithine decarboxylase, S-adenosylmethionine decarboxylase, gamma-glutamyl transpeptidase, and transglutaminase. See, for example, Breuer et al., U.S. Pat. No. 4,885,289; Shander,

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U.S. Pat. No. 4,720,489; Ahluwalia, U.S. Pat. No. 5,095,007; Ahluwalia et al., U.S. Pat. No. 5,096,911; Shander et al., U.S. Pat. No. 5,132,293; and Shander et al., U.S. Pat. No. 5,143,925.

The growth of hair results from many complex and interactive processes. In one process sex steroid androgens, particularly testosterone, act on, for example, beard hair follicles on the face to stimulate hair growth. But these same androgens can inhibit hair growth on the scalp, particularly in those that have a genetic predisposition for male-pattern baldness or androgenetic alopecia.

Cytochrome P450s, epoxide hydrolases, glutathione-S-transferases, uridine diphosphate ~~UDP~~-glucuronosyltransferases (UGTs), and sulfotransferases (STs) are families of enzymes that are involved in the metabolism of xenobiotics and other substances that are endogeneous to the human body. Generally, the enzymes catalyze the conversion of a substrate (e.g., a particular steroid) to a form that is more readily eliminated from the body. For example, glutathione-S-tranferases catalyze the conjugation of the substrate with glutathione; UGTs catalyze the conjugation of substrate with glucuronic acid; and STs catalyze the conjugation of the substrate with a sulfonate moiety. It is believed that these substrate conjugates are more water soluble than the substrate itself, and thus more readily eliminated from the body. Some of these enzymes can be induced by compounds, such as 3-methylcholanthrene and phenobarbital.

Steroids are substrates for several isoforms of UGT, with overlapping specificities. For example, rat liver UGTr-3 catalyzes the glucuronidation of dihydrotestosterone, testosterone and β-estradiol, whereas in addition to these

steroids UGTr-2 also catalyzes 4-hydroxybiphenyl, chloramphenicol and 4-methylumbelliferone glucuronoconjugation (Chen et al., Biochem. 32: 10648-10657).

Summary of the Invention

In one aspect, the invention features modulating hair growth by topical application of a compound that induces or activates the conjugation of an androgen (e.g., testosterone) that is involved in hair growth. By "induces" or "activates", we mean that the compound increases the conjugating enzyme levels in the hair follicle cells and/or increases the catalytic activity of the conjugating enzyme for conjugation. The compound may, for example, induce or activate a UGT or an ST for which the androgen serves as the substrate.

The modulation in hair growth depends on whether the hair growth selected for treatment is androgen-stimulated hair growth (e.g., beard hair and torso hair generally in humans) or hair growth that is not androgen-stimulated (e.g., scalp hair in humans). Topical application of the compound in a dermatologically acceptable vehicle to an area of skin having androgen-stimulated hair growth generally causes a reduction in hair growth. Topical application of the compound in a dermatologically acceptable vehicle to an area of skin having hair growth (i.e., from the scalp) that is reduced in the presence of androgens, (e.g., because of androgenic alopecia) generally causes an increase in hair growth.

In another aspect, the invention features modulating hair growth by topical application of a compound that induces or activates a UGT.

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In another aspect, the invention features modulating hair growth by topical application of a compound that induces or activates an ST.

In another aspect, the invention features modulating hair growth by topical application of a compound that induces or activates the conversion of an androgen involved in hair growth to a less active (e.g., more water soluble) metabolite.

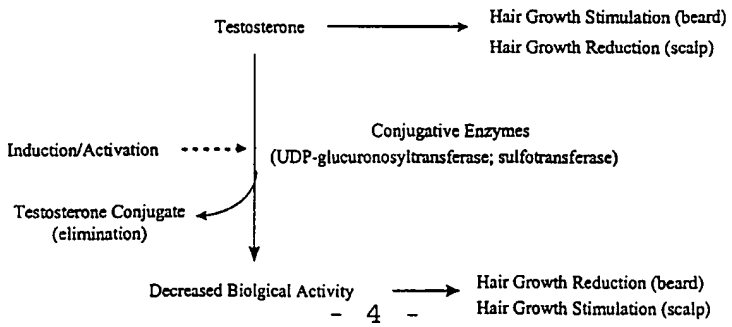
Other features and advantages of the invention will be apparent from the Description of Preferred Embodiments thereof, and from the claims.

Description of Preferred Embodiments

Compounds that activate or induce UGTs are known. Such compounds include ethoxyquin, 5,7-dihydroxy-4'-methoxyflavone, butylhydroxyanisole, phenobarbital, naringenin, butylhydroxytoluene, flavone, tioconazole, trans-1,2-bis(2-pyridyl)ethylene, 7,4'-isoflavandiol, (equol), galangin, 7-hydroxy-4'-methoxyisoflavone (formononetin), 5,4'-dihydroxy-7-methoxyisoflavone (prunetin), and daidzein. These compounds induce UGTs relevant to testosterone glucononidation.

Examples of androgens that may be conjugated include testosterone, dihydrotestosterone, androstenedione, androstenediols, and dehydroepiandrosterone.

It is believed that the compounds act according to the pathway shown below (in which testosterone is used as an example):



The compound may induce or activate, for example, UGTs that catalyze the conjugation of testosterone with glucuronic acid (donated from uridine diphosphoglucuronic acid) or STs that catalyze the conjugation of testosterone with a sulfonate group (donated from 3'-phosphoadenosine 5'-phosphosulfate).

The compound preferably is incorporated in a topical composition that includes a non-toxic dermatologically acceptable vehicle or carrier which is adapted to be spread upon the skin. Examples of suitable vehicles are acetone, alcohols, or a cream, lotion, or gel which can effectively deliver the active compound. A vehicle is disclosed in U.S. Patent No. 5,648,394. In addition, a penetration enhancer may be added to the vehicle to further enhance the effectiveness of the formulation.

The concentration of the compound in the composition may be varied over a wide range up to a saturated solution, preferably from 0.1% to 30% by weight or even more; the reduction or increase in hair growth rises as the amount of inhibitor applied increases per unit area of skin. The maximum amount effectively applied is limited only by the rate at which the compound penetrates the skin. The effective amounts may range, for example, from 10 to 3000 micrograms or more per square centimeter of skin.

A composition may include more than one of the compounds.

The composition should be topically applied to a selected area of the body from which it is desired to reduce hair growth (if the hair growth is androgen-stimulated hair growth) or increase hair growth (if the hair loss is androgen dependent). For example, in humans the composition can be applied to the face, particularly to the beard area of the face, i.e., the cheek, neck, upper lip, and chin to

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obtain a reduction in hair growth. The composition can also be applied to the legs, arms, torso or armpits to obtain a reduction in hair growth. The composition can be applied to the scalp to obtain an increase in hair growth. The composition is particularly suitable for reducing the growth of unwanted hair in women suffering from hirsutism or other similar conditions.

In humans, the composition, for example, may be applied once or twice a day, or even more frequently, for two weeks to six months (e.g., three months) to achieve a perceived effect. Reduction in hair growth is demonstrated when the frequency of hair removal is reduced or the subject perceives less hair on the treated site, or quantitatively, when the weight of hair removed by shaving (i.e., hair mass) is reduced. Increase in hair growth is demonstrated when the opposite effect is observed.

Male intact Golden Syrian hamsters are considered acceptable models for human beard hair growth and other androgen-stimulated hair growth in that they display oval shaped flank organs, one on each side, each about 8 mm. in major diameter, which grow thick black and coarse hair similar to human beard hair. These organs produce hair in response to androgens in the hamster. To evaluate the effectiveness of a composition in reducing androgen-stimulated hair growth, the flank organs of each of a group of hamsters are shaved. To one organ of each animal 10 μl. of composition vehicle alone once a day is applied, while to the other organ of each animal an equal amount of the composition (including the relevant compound or compounds). After thirteen applications (one application per day for five days a week), the flank organs are shaved and the amount of recovered hair (hair mass) from each is weighed. Percent-reduction of hair growth is calculated by

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subtracting the hair mass (mg) value of the test compound treated side from the hair mass value of the vehicle treated side; the delta value obtained is then divided by the hair mass value of the vehicle treated side, and the resultant number is multiplied by 100.

The above-described assay will be referred to herein as the "Golden Syrian hamster" assay. Preferred compositions provide a reduction in hair growth of at least about 30%, more preferably at least about 50%, and most preferably at least about 60% when tested in the Golden Syrian hamster assay.

A number of compositions containing compounds that induce or activate UGTs for which testosterone is a substrate were tested in the Golden Syrian hamster assay; the results are provided in Table I:

TABLE I

Compound	Vehicle	Left (mg)	Right (mg)	% Inhibition
ethoxyquin	A	0.55 ± .16	2.41 ± .11	75 ± 7
5,7-dihydroxy-4'-methoxyflavone	B	1.00 ± .22	2.61 ± .27	62 ± 9
butylhydroxyanisole	A	0.92 ± .24	2.27 ± .11	61 ± 9
phenobarbital	A	0.89 ± .16	1.88 ± .24	51 ± 11
naringenin	A	1.42 ± .18	2.46 ± .20	40 ± 8
butylhydroxytoluene	C	1.74 ± .38	2.05 ± .36	22 ± 18
flavanone	C	1.91 ± .22	2.39 ± .22	17 ± 10

All compounds were administered as a 10% does. Vehicle A = ethanol 80%, H_2O 17.5%, propylene glycol dipelargonate 2%, propylene glycol 0.5%; B = ethanol 70%, dimethylsulfoxamine 30%; C = propylene glycol 50%, ethanol 25%, dimethylsulfoxide 25%.

An assay was performed to evaluate whether some of the compounds tested in the Golden Syrian Hamster assay caused an induction of testosterone glucuronide formation.

Flank organ homogenates were prepared by adding 4 flank organs into 2 mL of a buffer containing 25 mM Tris/50 mM sucrose, pH 7.4 and homogenized with a Polytron (Brinkman Instruments) while keeping the mixture on ice. The

glucuronidation of testosterone was measured by incubating the 20 μl of the flank organ protein (1 mg/ml) with [^{14}C]-testosterone 125μM and UDP-glucuronic acid (5mM) in the presence of buffer containing 0.5M Tris, pH 7.5 and 0.1 M $MgCl_2$. The total reaction mixture volume was 100 μl. Assay mixtures were incubated at 37°C for 60 minutes, and reactions were stopped with the addition of 3.5 ml methylene chloride. An aqueous carrier (250 μl water) was added to each reaction mixture which was then shaken and centrifuged. The unmetabolized [^{14}C]-testosterone remained in the organic phase whereas the testosterone glucuronide partitioned into the aqueous phase, and was quantitated by scintillation spectrometry. The results are provided in Table II:

TABLE II

Compound	% Induction
ethoxyquin	214
butylhydroxyanisole	178
5,7-dihydroxy-4'-methoxyflavone	120
phenobarbital	113

It was believed that the diversion of testosterone away from its biologically active species to a glucuronide or sulfonate conjugate would have effects on the flank organs of the Golden Syrian hamster since testosterone is known to regulate the existence of these unique organs. The diameter of flank organs were assessed using a caliper following topical treatment of the hamsters with ethoxyquin or 5,7-dihydroxy-4'-methoxyflavone as described in the hair mass assay section. A decrease in flank organ diameter was demonstrated following topical application of the compounds (Table III). These data are consistent with the hypothesis that suggests that local induction of conjugating enzymes, such as UGTs, can diminish the biological activity of testosterone.

TABLE III

Treatment	Treated FO (mm)	Vehicle FO (mm)	Decrease (mm)	% Decrease
ethoxyquin	7.18 ± .26	8.83 ± .28	1.65 ± .37	19 ± 4
5,7-dihydroxy-4'-methoxyflavone	8.04 ± .29	9.08 ± .43	1.04 ± .46	12 ± 5

Other embodiments are within the claims.